Robust InSAR Tropospheric Delay Correction Using Global Atmospheric Models

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Tropospheric delays are the main source of error when measuring ground displacements using InSAR. Increasingly, global atmospheric models (GAMs), e.g., ERA5 and MERRA2 reanalysis data, are used to reduce tropospheric signals in InSAR deformation observations. However, due to the coarse spatial resolution of current GAMs (~10s of kilometers), it is still challenging to obtain tropospheric corrections for high-resolution InSAR data (~10s of meters). Here we present an advanced GAM-based correction method, aimed at improving InSAR geodesy, that incorporates spatial stochastic models of the troposphere in the corrections. We first estimate stochastic models of the tropospheric parameters (temperature, pressure, and partial pressure of water vapor) at different GAM altitude layers and we then interpolate the parameters according to the correlation between pixels of interest and the GAM grid locations (3D). The interpolation accounts for spatial variabilities of the tropospheric random field, instead of subjectively using an inverse distance method or using a local spline function, which are commonly used in current GAM-correction methods. We also estimate the integral of the tropospheric delays along the satellite line-of-sight (LOS) direction directly, instead of calculating the projected zenith-delays, because the troposphere is not purely stratified. Our new method can easily be applied using any of the present GAMs; here we implemented it with the latest ECMWF ERA5 reanalysis outputs. We validate the new method for both interferograms and time-series analysis products (deformation velocities and time-series solutions), using hundreds of the Sentinel-1 images over the island of Hawaii from 2015 to 2020. The results show that the average standard deviation of non-deforming interferograms reduces from 2.55 cm to 1.91 cm when applying the new method, compared with standard deviations of 2.47 cm (PyAPS), 2.44 cm (d-LOS), and 2.10 cm (GACOS), after using three common GAM correction methods. In addition, the new method improves most (87%, i.e., 243 out of 280) of the interferograms, while only about half (52%, 53%, and 66%) are improved by the earlier correction methods. The results demonstrate the importance of considering (1) tropospheric stochastic models in GAM-corrections, (2) horizontal heterogeneities when estimating the LOS delays, and (3) tropospheric delays when mapping long-wavelength or small-magnitude deformation using InSAR.